Ferroelectric/Piezoelectric-Diamond Hybrid Hetero-structures for High Performance MEMS/NEMS Device

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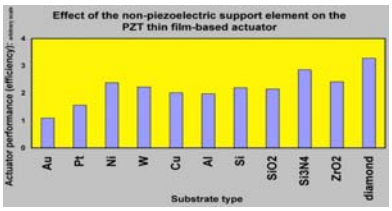
Motivation

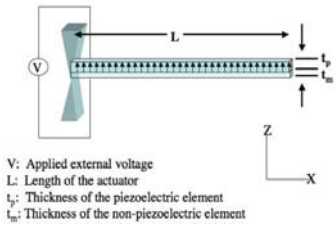
Integration of ultra nano-crystalline diamond (UNCD) layers with outstanding mechanical, tribological and biocompatible properties with ferroelectric/piezoelectric functional materials for new generation MEMS/NEMS devices

Major Accomplishments

Theory indicates that integration of functional piezoelectric and UNCD materials produces optimized MEMS/NEMS device performance

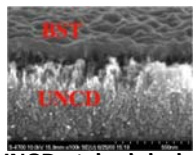


Analytical expressions were derived to calculate the dynamic behavior of MEMS/NEMS actuators/sensors for different materials integrated with PZT (diamond is the best substrate)



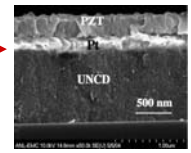
Schematic of PZT/UNCD actuator

Experimental demonstration of high-K dielectric and piezoelectric $PbZr_xTi_{1-x}O_3$ (PZT) thin film / UNCD layer integration



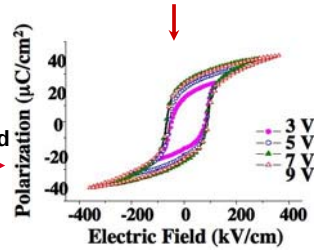
UNCD etched during $BaSr_xTi_{1-x}O_3$ oxide film growth on top

TiAl (10 nm)
O_2 diffusion barrier

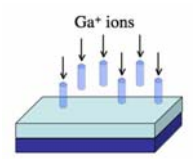


sharp interface between UNCD and PZT

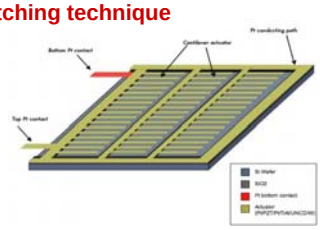
First Pt/PZT/Pt/TiAl/ capacitor structure Grown on UNCD substrate demonstrated with excellent polarization properties



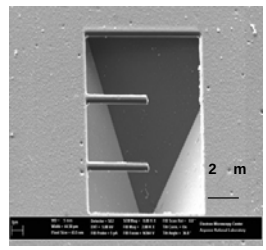
Fabrication of micro/nano UNCD cantilevers using the focused ion beam (FIB) etching technique

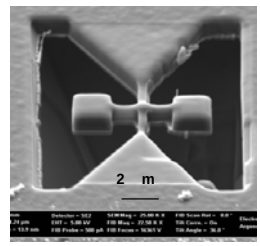


Schematic of the FIB method to fabricate UNCD cantilevers



1st prototype of micro and nano PZT/UNCD actuators on chip for MEMS/NEMS devices

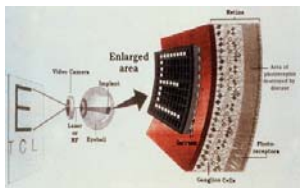




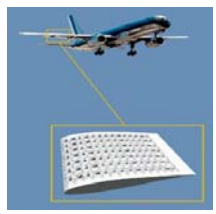
SEM images of UNCD cantilevers and paddle resonators fabricated using FIB, for subsequent growth of TiAl/Pt/PZt/Pt Heterostructure to demonstrate piezoactuation of UNCD cantilevers

Impact

Successful Piezomaterial/UNCD integration will revolutionize the fields of medicine, defense and semiconductors with the next generation UNCD based MEMS/NEMS devices



Bioinertness of UNCD opens way to MEMS/NEMS biodevices (e.g. piezoelectric pressure sensor for artificial retina with Pb-free biocompatible piezoelectric layer)

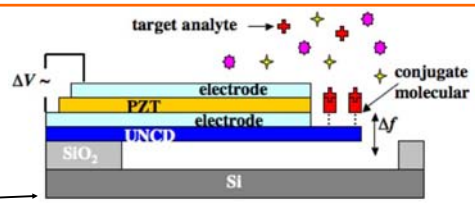


Piezoelectric MEMS sensors and actuators for drag reduction on aircraft (NASA LaRC).

piezoelectric sensors under the seat deploy an air bag more softly if the passenger is in a dangerous position

Future Directions

- **Optimization of processing for integration of functional PZT films on UNCD cantilevers for MEMS/NEMS applications**
- **Characterization of PZT/UNCD cantilevers performance**
- **Extend the integration to other functional (eg. Multiferroics) materials on UNCD**
- **Demonstration of hybrid PZT/UNCD sensor**



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